PROPERTIES OF OIL PALM SHELL LIGHTWEIGHT AGGREGATE CONCRETE CONTAINING UNGROUND PALM OIL FUEL ASH AS FINE AGGREGATE REPLACEMENT

MOHD HANAFI BIN HASHIM

MASTER OF SCIENCE

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

We hereby declare that We have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

_____

(Supervisor's Signature)

Full Name : KHAIRUNISA BINTI MUTHUSAMY

Position : ASSOCIATE PROFESSOR

Date :

_____

(Co-supervisor's Signature)

Full Name : SAFFUAN WAN AHMAD

Position : SENIOR LECTURER

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

_____

(Student's Signature)

Full Name : MOHD HANAFI BIN HASHIM

ID Number : MAC 16003

Date :

PROPERTIES OF OIL PALM SHELL LIGHTWEIGHT AGGREGATE CONCRETE CONTAINING UNGROUND PALM OIL FUEL ASH AS FINE AGGREGATE REPLACEMENT

MOHD HANAFI BIN HASHIM

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Master of Science

Faculty of Civil Engineering Technology

UNIVERSITI MALAYSIA PAHANG

SEPTEMBER 2020

ACKNOWLEDGEMENTS

Firstly, I would like to express my sincere gratitude to my supervisor Assoc. Prof. Dr. Khairunisa Bt Muthusamy and my co-supervisor Ir. Dr. Saffuan Bin Wan Ahmad for the continuous support during my period of study. Their guidance helped me in all the time of research and writing of the thesis. I could not have imagined having a better advisor and mentor for my master study.

I would also like to express my sincere thanks to all laboratory staffs at the Structural and Material Laboratory in Faculty of Civil Engineering and Earth Resources of Universiti Malaysia Pahang for their guidance, help, encouragement, support and assistance given throughout my research programme. I would like to extend my gratitude to the entire management team of palm oil mill in Pahang for their cooperation and contribution in providing the palm oil wastes.

I am highly indebted to my mother, Rahmi Bt Md Salim and also my wife Siti Normaziah Bt Ihsan for their continuous support that made every opportunity available to me throughout my life.

I thank my fellow research mates Mohd Nazrin Akmal Bin Ahmad Zawawi, Mohd Hafizuddin Bin Rasid and Nur Azzimah Bt Zamri for the stimulating discussions, useful knowledge which we shared while working together and for all the happiness and tears we had in the last 2 years.

Lastly, I would like to acknowledge the financial support from government of Malaysia through their full sponsorship and thank you all to those people who have been involved in taking care of me during my master studies in Universiti Malaysia Pahang.

ABSTRAK

Kerosakan alam sekitar yang disebabkan peningkatan aktiviti pengkuarian batu baur granit dan pasir bagi memenuhi keperluan industri pembinaan adalah suatu isu yang perlu diselesaikan. Pada masa yang sama, aktiviti pembuangan tempurung kelapa sawit (OPS) dan abu terbang kelapa sawit (POFA) dari kilang pemprosesan minyak sawit menyebabkan pencemaran alam. Demi memastikan kelestarian sumber batu granit dan industri minyak sawit yang mesra alam, penyelidikan ini dijalankan untuk mengintegrasikan sisa buangan sawit tersebut sebagai aggregat di dalam konkrit. Justeru itu, penyelidikan ini mengkaji kesan penggunaan POFA sebagai bahan separa pengganti pasir terhadap sifat mekanikal dan ketahanlasakan konkrit aggregat ringan. Pada peringkat awalan, bancuhan percubaan telah dibuat untuk mendapatkan campuran konkrit yang paling optimum dengan campuran yang sesuai. Kesan awetan udara dan air terhadap kekuatan mampatan, kekuatan pemisahan, kekuatan lenturan dan *modulus* keanjalan konkrit yang mengandungi POFA sebanyak 0%, 10%, 15% dan 20% sebagai bahan separa pengganti pasir turut dilaporkan. Kajian turut dijalankan terhadap ketahanlasakan konkrit mengandungi POFA dari segi rintangan terhadap serangan asid, sulfat dan pengkarbonatan. Hasil kajian menunjukkan sampel konkrit dengan 10% POFA yang direndam di dalam air menunjukkan kekuatan tertinggi. Ini disebabkan oleh kesan tindakbalas pozzolan dan pengisi oleh POFA yang meningkatkan kepadatan dan kekuatan konkrit. Walau bagaimanapun, penggunaan POFA 20% menghasilkan konkrit dengan kekuatan terendah. Penggunaan awetan air membantu konkrit yang mengandungi POFA mencapai kekuatan mampatan, lenturan, tegangan dan modulus keanjalan yang lebih tinggi berbanding sampel awetan udara. Konkrit agregat ringan yang mengandungi 10% POFA juga menunjukkan rintangan tertinggi terhadap serangan asid, sulfat dan pengkarbonatan. Semua sampel konkrit aggregate ringan diklasifikasikan sebagai konkrit berkualiti kerana menyerap air kurang daripada 10% ketika ujian serapan air dijalankan. Konkrit yang diawet di dalam air sehingga 365 hari tidak menunjukkan kesan pengkarbonatan. Pengawetan air membantu memastikan proses penghidratan dan tindakbalas pozzolan dapat mengurangkan kalsium hidroksida dan meningkatkan CSH gel yang boleh meningkatkan ketahanankonkrit. Kesimpulannya, kejayaan dalam menggunakan abu terbang kelapa sawit sebagai bahan separa pengganti pasir di dalam penghasilan konkrit agregat ringan dapat mengurangkan kuantiti penggunaan pasir semulajadi yang dilombong dari sungai dan mengurangkan jumlah sisa kilang sawit yang dibuang di tapak pelupusan.

ABSTRACT

Environmental degradation due to increasing granite aggregate quarrying and river sand mining to supply the construction industry needs is an issue which need to be solved. At the same time, the disposal of oil palm shells (OPS) and palm oil fuel ash (POFA) from palm oil mills is causing environmental pollution. In view of sustained supply of natural aggregate and a more environmental friendly palm oil industry, the present research attempt to integrate both palm oil wastes as alternative aggregates in concrete. Thus, this research investigates the effect of unground POFA content as partial fine aggregate replacement towards mechanical and durability of OPS lightweight aggregates concrete. At the first stage, trial mix has been conducted to select the optimum lightweight concrete mix design. The effect of air and water curing regime on this environmental friendly concrete containing unground POFA ranging from 5%, 10%, 15% and 20% by weight of sand were examined in term of the compressive strength, splitting strength, flexural strength and modulus of elasticity for a duration of 1 year. Testing on durability performance of the concrete specimens in the aspect of acid resistance, sulphate resistance and carbonation has been conducted. The finding shows that water cured OPS LWAC with 10% of unground POFA as sand replacement performs the best amongst all concrete specimens. The application of optimum amount of sand replacement resulted in a better densification from the pozzolanic reaction and filler effect by unground POFA thus making the OPS LWAC denser and stronger. However, inclusion of unground POFA up to 20% produces concrete with the lowest mechanical strength values. As for curing effect, the water curing specimen shows better result in term of compressive, flexural, splitting and modulus of elasticity compare with the air curing specimen. Water cured OPS LWAC containing 10% of unground POFA achieve higher durability against acid and sulphate attack compare with the other specimen. All specimens for air and water curing present the good result in term of water absorption testing where the result is below than 10% which is represent as a good quality of concrete. No carbonation rate was detected for specimen subjected to water curing until the age of 365 days. Air cured specimens begins to carbonate at age of 180 days where specimen contain 10% amount of unground POFA have the lowest carbonation value compare with control specimen and the other percentage of replacement specimen. Water curing promotes undisturbed hydration process and pozzolanic reaction which enhances the durability of OPS LWAC specimen with 10% POFA as compared to the air cured ones. Conclusively, success in utilizing unground POFA as partial fine aggregate replacement in OPS lightweight aggregate concrete would reduce quantity of natural sand mined from the river and amount of palm oil solid waste disposed at landfill.

TABLE OF CONTENT

REFERENCES

Abdul Awal, A. S. M. A Study Of Strength And Durability Performances Of Concrete Containing Palm Oil Fuel Ash. Ph.D. Thesis. University Teknologi Malaysia; 1998

Adnan Flayih Hassan Al-Sibahy. (2016). EFFECTS OF SUPERPLASTICIZER ADMIXTURE ON THE MECHANICAL BEHAVIOUR OF LIGHTWEIGHT CONCRETE بلع ةيواحلاو نزولا ةفيفخلا ةناسرخلل يكيناكيملا فرصتلا بلع قوفتملا ندلملا ريثأت يندعملا فاضملا, *9*(2), 148–160.

Ahmad Zawawi, M.N.A., Muthusamy, K., P.P Abdul Majeed, A., Muazu, R., Budiea, A.M.A.Mechanical properties of oil palm waste lightweight aggregate concrete with fly ash as fine aggregate replacement, Journal of Building Engineering,

Alengaram, U. J., Muhit, B. A. Al, & Jumaat, M. Z. Bin. (2013). Utilization of oil palm kernel shell as lightweight aggregate in concrete - A review. *Construction and Building Materials*, *38*, 161–172.

Alqahtani, F. K., Ghataora, G., Khan, M. I., & Dirar, S. (2017). Novel lightweight concrete containing manufactured plastic aggregate. *Construction and Building Materials*, *148*, 386–397.

Al-Sibahy, A. F. H. (2016). EFFECTS OF SUPERPLASTICIZER ADMIXTURE ON THE MECHANICAL BEHAVIOUR OF LIGHTWEIGHT CONCRETE MIXES CONTAINING MINERAL ADDITIVES. Al-Qadisiyah Journal for Engineering Sciences, 9(2), 148-160.

Aslam, M., Shafigh, P. & Jumaat, M.Z. (2016). Oil-palm by-products as lightweight aggregate in concrete mixture: a review. *Journal of Cleaner Production*, *126*, 56-73

Ashraf M A Maah M J Yusof I Wajid A and Mahmood K (2011) Sand mining effects, causesand concerns: A case study from Bestari Jaya, Selangor, Peninsular Malaysia. *Scientific Research and Essays* 6(6) : 1216-1231

ASTM C494-05, 2005. Standard Specification for Chemical Admixtures for Concrete. American Society of Testing and Materials.

ASTM C330 (2017) Standard Specification for Lightweight Aggregates for Structural Concrete, American Society of Testing Material, West Conshohocken, PA, .

ASTM C1012. (2004). Standard Method for Length Change of Hydraulic Cement Mortars Exposed to A Sulphate Solution. West Conshohocken, PA:

ASTM C496 (2017) Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, American Society of Testing Material, West Conshohocken, PA.

ASTM C494 (2017) American Standard Testing of Materials – Standard Specification for Chemical Admixtures for Concrete, American Society of Testing Material, West Conshohocken, PA.

Awal, A. S. M. A., & Shehu, I. A. (2015). Performance evaluation of concrete containing high volume palm oil fuel ash exposed to elevated temperature. *Construction and Building Materials*, *76*, 214–220.

Bakharev, T., Sanjayan, J. G., & Cheng, Y. (2003). Resistance of alkali-activated slag concrete to acid attack, *33*, 1607–1611.

Bassuoni, M. T., & Nehdi, M. L. (2007). Resistance of self-consolidating concrete to sulfuric acid attack with consecutive pH reduction. *Cement and Concrete Research*, *37*(7), 1070–1084.

Bellmann F, Erfurt W and Ludwig H-M (2012) Field performance of concrete exposed to sulphate and low pH conditions from natural and industrial sources. *Cement and Concrete Composites* 34(1): 86–93

Bertolini, L., Elsener, B., Pedeferri, P., Redaelli, E., & Polder, R. (2013). Corrosion of steel in concrete (Vol. 392). Weinheim, Germany: Wiley-Vch.

Brown, O. R., Yusof, M. B. B. M., Salim, M. R. Bin, & Ahmed, K. (2011). Physico-chemical properties of palm oil fuel ash as composite sorbent in kaolin clay landfill liner system. *2011 IEEE 1st Conference on Clean Energy and Technology, CET 2011*, *1*, 269–274.

Board, M.P.O., 2017. Production of crude palm oil for the month of March 2017, 1 April 2017 ed, Malaysia

BS 1881 - 121 (1983) Testing Concrete, Method for Determination of Static Modulus of Elasticity in Compression.

BS 1881 - 122 (1983) Testing concrete, Method for Determination of Water Absorption.

BS EN 12350-2 (2009) Testing Fresh Concrete: Slump-Test.

BS EN 12390-3 (2009) Testing Hardened Concrete : Compressive Strength of Test Specimens.

BS EN 12390-5 (2009) Testing hardened concrete : Flexural strength of test specimens, 2009.

BS EN 14630. (2006). Products and Systems for the Protection and Repair Of Concrete Structures-Test Methods-Determination of Carbonation Depth in Hardened Concrete By The Phenolphthalein Method. London: The British Standard.

Cartuxo, F., De Brito, J., Evangelista, L., Jiménez, J. R., & Ledesma, E. F. (2015). Rheological behaviour of concrete made with fine recycled concrete aggregates - Influence of the superplasticizer. *Construction and Building Materials*, *89*, 36–47.

Chen, Y., Gao, J., Tang, L., & Li, X. (2016). Resistance of concrete against combined attack of chloride and sulfate under drying-wetting cycles. *Construction and Building Materials*, *106*, 650–658.

Chong, H. L. H., Chia, P. S., Ahmad, M. N.The adsorption of heavy metal by Bornean oil palm shell and its potential application as constructed wetland media, *Bioresources Technology*. 130 (2013) 181-186.

Chang, Zhen-Tian & Song, Xiu-Jiang & Munn, Robert & Marosszeky, Marton. (2005). Using limestone aggregates and different cements for enhancing resistance of concrete to sulphuric acid attack. *Cement and Concrete Research*. 35. 1486-1494. 10.1016/j.cemconres.2005.03.006.

Clarke, J.L. (2002). *Structural lightweight aggregate concrete*. http://doi.org/10.1016/B978-075065686-3/50313-X

Ashish, D. K. (2018). Feasibility of waste marble powder in concrete as partial substitution of cement and sand amalgam for sustainable growth. Journal of Building Engineering, 15, 236-242.

Department of Mineral and Geoscience, Malaysia.(2016) http://malaysianminerals.com/index.php?option=com_content&task=view&id=21&Itemid=45

Demirdag, S., Ugur, I., & Sarac, S. (2008). The effects of cement/fly ash ratios on the volcanic slag aggregate lightweight concrete masonry units. *Construction and Building Materials*, *22*(8), 1730–1735.

Duan, Z.H., Kou, S.C, & Poon, C.S. (2013). Prediction of compressive strength of recycled aggregate concrete using artificial neural networks. *Construction and Building Materials*, *40*, 1200–1206.

Ekolu, S. O. (2016). A review on effects of curing, sheltering, and CO2 concentration upon natural carbonation of concrete. Construction and Building Materials, 127, 306-320.

Economics & Industry Development Division, (2017). Overview of the Malaysian Oil Palm Industry. Malaysian Palm Oil Board, Kelana Jaya, Malaysia Retrieved from. http://bepi.mpob.gov.my/images/overview/Overview_of_Industry_2016.pdf.

Farahani, N., Shafigh, P., Al-Subari, B., Shanazard, S. and Mahmud, H. (2017).Engineering properties of lightweight aggregate concrete containing binary and ternary blended cement. *Journal of Cleaner Production*, 149, 2017, 976-988

Ganesh, P.G., Hyun, J.H. and Kim, Y.Y. (2014) Effects of foundry sand as a fine aggregate inconcrete production, *Construction and Building Materials*, *70*, 514-521.

Ghannam, S., Najm, H., & Vasconez, R. (2016). Experimental study of concrete made with granite and iron powders as partial replacement of sand. *SUSMAT*, *9*, 1–9.

Güneyisi et al. (2015). Utilization of cold bonded fly ash lightweight fine aggregates as a partial substitution of natural fine aggregate in self-compacting mortars. *Construction and Building Materials*, *74*, 9–16.

Hadigheh, S. A., Gravina, R. J., & Smith, S. T. (2017). Effect of acid attack on FRP-to-concrete bonded interfaces. *Construction and Building Materials*, *152*, 285–303.

Haghighatnejad, N., Mousavi, S. Y., Khaleghi, S. J., Tabarsa, A., & Yousefi, S. (2016). Properties of recycled PVC aggregate concrete under different curing conditions. *Construction and Building Materials*, *126*, 943–950.

Hainin, M. R., Yusoff, N. I. M., Sabri, M. F. M., Aziz, M. A. A., Hameed, M. A. S., and Reshi, W. F. (2012). "Steel slag as an aggregatereplacement in Malaysian hot mix asphalt." *International Scholarly Research Network*, pp. 1-5

Hashim, H., & Ho, W. S. (2011). Renewable energy policies and initiatives for a sustainable energy future in Malaysia. Renewable and Sustainable Energy Reviews, 15(9), 4780-4787.

Hansen, Sune Balle, et al. "Trends in global palm oil sustainability research." Journal of cleaner Production 100 (2015): 140-149.

Huber, B., Hilbig, H., Mago, M. M., Drewes, J. E., & Müller, E. (2016). Comparative analysis of biogenic and chemical sulfuric acid attack on hardened cement paste using laser ablation-ICP-MS. *Cement and Concrete Research*, *87*, 14–21. http://doi.org/10.1016/j.cemconres.2016.05.003

Hamada, H. M., Thomas, B. S., Tayeh, B., Yahaya, F. M., Muthusamy, K., & Yang, J. (2020). Use of oil palm shell as an aggregate in cement concrete: A review. Construction and Building Materials, 265, 120357.

Hedjazi, S. (2019). Compressive strength of lightweight concrete. In Compressive Strength of Concrete. IntechOpen.

Ibrahim, H. A., Razak, H. A., & Abutaha, F. (2017). Strength and abrasion resistance of palm oil clinker pervious concrete under different curing method. *Construction and Building Materials*, *147*, 576–587. http://doi.org/10.1016/j.conbuildmat.2017.04.072

Islam, M. M. U., Mo, K. H., Alengaram, U. J., & Jumaat, M. Z. (2016). Mechanical and fresh properties of sustainable oil palm shell lightweight concrete incorporating palm oil fuel ash. *Journal of Cleaner Production*, *115*, 307–314. http://doi.org/10.1016/j.jclepro.2015.12.051

Johannesson, B., & Utgenannt, P. (2001). Microstructural changes caused by carbonation of cement mortar. Cement and concrete Research, 31(6), 925-931

Kockal, N. U. (2016). Investigation about the effect of different fine aggregates on physical, mechanical and thermal properties of mortars. *Construction and Building Materials*, *124*, 816–825. http://doi.org/10.1016/j.conbuildmat.2016.08.008

Kropp, J., & Hilsdorf, H. . (2005). *Performance Criteria for concrete Durability*.

Laichaoui, A., Zidol, A., Mitiche-Kettab, R., Bali, A., & Tagnit-Hamou, A. (2019). Effect of the type of superplasticizer on the properties of cementitious systems incorporating slag. Journal of Adhesion Science and Technology, 33(2), 187-207.

Lee, S.T (2008) Effect of curing procedures on the strength and permeability of cementitious composites incorporating GGBFS. Journal of Ceramic Processing Research. 9(4), 358- 361

Liu, J.H., Shi, C.J., Farzadnia, N and Ma, X.W (2019) Effects of pretreated fine lightweight aggregate on shrinkage and pore structure of ultra-high strength concrete, *Construction and Building Materials*, 204, 276-287

Malaysian Mineralogical Department, (2010) Towards Sustainable Construction Bulletin 2010. Technical Report. Malaysia.

MS 522: Part 1 (2003) Portland cement (ordinary and rapid-hardening) Part 1: specification (second revision) Department of Standards Malaysia.

Mailar, G., Sreedhara, B. M., Manu, D. S., Hiremath, P., & Jayakesh, K. (2016). Investigation of concrete produced using recycled aluminium dross for hot weather concreting conditions. Resource-Efficient Technologies, 2(2), 68-80.

Mannan, M. A. and Ganapathy, C. (2001). "Mix design for oil palm shell concrete." *Cement and Concrete Research*, 31(9), pp. 1323-1325,

Mannan, M.A. and Ganapathy, C. 2004. Concrete from an agricultural waste-oil palm shell (OPS). *Building and Environmental*, 39: 441-448.

Mannan, M. A., Alexander, J., Ganapathy, C., & Teo, D. C. L. (2006). Quality improvement of oil palm shell (OPS) as coarse aggregate in lightweight concrete. *Building and Environment*, *41*(9), 1239–1242.

Mangi, S.A., Wan Ibrahim, M.H., Jamaluddin, N., Arshad, M.F., Putra Jaya, R. (2019)Short-term effects of sulphate and chloride on the concrete containing coal bottom ash as supplementary cementitious material, *Engineering Science and Technology, an International Journal*, 22(2), 515-522

Manoharan, T., Laksmanan, D., Mylsamy, K., & Sivakumar, P. (2018). Engineering properties of concrete with partial utilization of used foundry sand. *Waste Management*, *71*, 454–460.

Manomi, N., Sathyan, D., & Anand, K. B. (2018). Coupled effect of superplasticizer dosage and fly ash content on strength and durability of concrete. Materials Today: Proceedings, 5(11), 24033-24042.

Merida, A., & Kharchi, F. (2015). Pozzolan concrete durability on sulphate attack. Procedia Engineering, 114(2015), 832-837.

Mo, K. H., Alengaram, U. J., Jumaat, M. Z., Liu, M. Y. J., & Lim, J. (2016). Assessing some durability properties of sustainable lightweight oil palm shell concrete incorporating slag and manufactured sand. *Journal of Cleaner Production*, *112*, 763–770.

Moayeri, M., Ashrafi, H., & Beiranvand, P. (2016). Investigating the Physical Characteristics of Non-Structural Lightweight Aggregate Blocks of Built with Region Materials. *Buildings*, *7*(1), 2.

MPOB (2018) Overview of the Malaysian Oil Palm Industry 2017.http://bepi.mpob.gov.my/images/overview/Overview_of_Industry_2017.pdf

MPOB (2018) Export trend 2018. http://bepi.mpob.gov.my/index.php/en/statistics/export/192-export-2018/868-export-trend-2018.html

Munir, A., Abdullah, Huzaim, Sofyan, Irfandi, & Safwan. (2015). Utilization of palm oil fuel ash (POFA) in producing lightweight foamed concrete for non-structural building material. *Procedia Engineering*, *125*, 739–746.

Muntohar, A. S., & Rahman, M. E. (2014). Lightweight masonry block from oil palm kernel shell. *Construction and Building Materials*, *54*, 477–484.

Mohammad M.U.l, Kim H.M., U. A.J. Alengaram, M.Z. Jumaat. Mechanical and fresh properties of sustainable oil palm shell lightweight concrete incorporating palm oil fuel ash. Journal of Cleaner Production. Volume 115, (2016), Pages 307 – 514.

Murthy, N. R. D., Ramaseshu, D., Rao, M. V. S. Studies on fly ash concrete under sulphate attack in ordinary, standard and higher grades at earlier ages, Asian Journal of Civil Eng. (Building and Housing). 8 (2007) 203-214.

Muthusamy, K., Zamri, N., Zubir, M. A., Kusbiantoro, A., & Ahmad, S. W. (2015). Effect of mixing ingredient on compressive strength of oil palm shell lightweight aggregate concrete containing palm oil fuel ash. *Procedia Engineering*, *125*, 804–810.

Muthusamy, K., Mirza, Zamri, N.A., Hussin, M.W., P.P. Abdul Majeed, A., Kusbiantoro, A. and Budiea, A.M.A (2019). Properties of high strength palm oil clinker lightweight concrete containing palm oil fuel ash in tropical climate. *Construction and Building Materials*, *199*, 163–177.

Neville, A. M. (2011) Properties of Concrete, Longman London.

Ngala, V.T. and Page, C.L. (1997). Effects of carbonation on pore structure and diffusional properties of hydrated cement pastes. *Cement and Concrete Research*. 27(7): 995-1007.

Öz, H. Ö. (2018). Properties of pervious concretes partially incorporating acidic pumice as coarse aggregate. *Construction and Building Materials*, *166*, 601–609.

Papadakis, V. G., Fardis, M. N., & Vayenas, C. G. (1992). Hydration and carbonation of pozzolanic cements. Materials Journal, 89(2), 119-130.

Parrot, L. (1992). Design for avoiding damage due to carbonation induced corrosion. April. Paper no. 62—CEN TC 104/WGl/TGl/Panel 1.

PMR (2017). Global Market Study on Construction Aggregates: Crushed Stone Product Type Segment Projected to Register High Value and Volume CAGR during 2017 – 2025 Persistence Market Research, New York, USA, p. 235

Radonjanin, R., Malesev, M., Marinkovic, S. Al Malty,A. E. S. (2013) Green recycled aggregate concrete,*Construction and Building Materials*,. 471503-1511.

Rashad, A. (2016). Cementitious materials and agricultural wastes as natural fine aggregate replacement in conventional mortar and concrete. Journal of Building Engineering, 5, 119-141.

Arora, S., & Singh, S. P. (2019). Probability of failure of RCA concrete with ternary blended cements. Construction and Building Materials, 225, 401-414.

Sairanen, Marjo, and Mikael Rinne. "Dust emission from crushing of hard rock aggregates." Atmospheric Pollution Research 10.2 (2019): 656-664.

Sata, V., Jaturapitakkul, C., & Kiattikomol, K. (2007). Influence of pozzolan from various by-product materials on mechanical properties of high-strength concrete. *Construction and Building Materials*, *21*(7), 1589–1598.

Sathiparan, N. &De ZoysaH. T. S. M. (2018) The effects of using agricultural waste as partial substitute for sand in cement blocks, Journal of Building Engineering. 19, 216-227.

Savija, B., & Lukovic, M. (2016). Carbonation of cement paste: Understanding, challenges, and opportunities. *Construction and Building Materials*, *117*, 285–301.

Shafigh, P., Jumaat, M. Z., & Mahmud, H. (2010). Mix design and mechanical properties of oil palm shell lightweight aggregate concrete: A review. *International Journal of the Physical Sciences*, 5(14), 2127-2134.

Shafigh, P., Mahmud, H. Bin, Jumaat, M. Z. Bin, Ahmmad, R., & Bahri, S. (2014). Structural lightweight aggregate concrete using two types of waste from the palm oil industry as aggregate. *Journal of Cleaner Production*, *80*, 187–196.

Shah, V., & Bishnoi, S. (2018). Carbonation resistance of cements containing supplementary cementitious materials and its relation to various parameters of concrete. *Construction and Building Materials*, *178*, 219–232.

Shettima, A. U., Hussin, M. W., Ahmad, Y., & Mirza, J. (2016). Evaluation of iron ore tailings as replacement for fine aggregate in concrete. *Construction and Building Materials*, *120*, 72–79.

Silva,R. V. de Brito, J, Dhir., R. K. Use of recycled aggregates arising from construction and demolition waste in new construction applications, *Journal of CleanerProduction*. 236, 1 2019, Article 117629

Singh, M., & Siddique, R. (2014). Compressive strength , drying shrinkage and chemical resistance of concrete incorporating coal bottom ash as partial or total replacement of sand, *68*, 39–48.

Skariah, B., Kumar, S., & Sahan, H. (2017). Sustainable concrete containing palm oil fuel ash as a supplementary cementitious material – A review, *80*(May), 550–561.

Skalny, J., Marchand, J., & Odler , I. (2002). Sulfate attack on concrete. London and New York: Taylor & Francis.

Sobuz, H.R., Hasan, N.M.S., Tamanna, N., Islam, M.S. (2014) Structural lightweight concrete production by using oil palm shell,*Journal of Materials*, 2014, Article ID 870247, 1-6

Stroh J, Schlegel MC, Irassar E, Meng B and Emmerling F (2014) Applying high resolution SyXRD analysis on sulfate attacked concrete field samples. *Cement and Concrete Research* 66: 19–26

Tanyildizi, H. (2018). Long-term performance of the healed mortar with polymer containing phosphazene after exposed to sulfate attack. *Construction and Building Materials*, *167*, 473–481.

Tchamdjou, W. H. J., Grigoletto, S., Michel, F., Courard, L., Abidi, M. L., & Cherradi, T. (2017). An investigation on the use of coarse volcanic scoria as sand in Portland cement mortar. *Case Studies in Construction Materials*, *7*(July), 191–206.

Teo, D. C. L., Mannan, M. A., Kurian, V. J., & Program, C. E. (2006). Structural Concrete Using Oil Palm Shell (OPS) as Lightweight, *30*, 251–257.

T. Z. H. Ting, M. E. Rahman, H. H. Lau, M. Z. Y. Ting, (2019)Recent development and perspective of lightweight aggregates based self-compacting concrete,*Construction and Building Materials*,201, 763-777.

Xiao, J., Qu, W., Li, W., & Zhu, P. (2016). Investigation on effect of aggregate on three non-destructive testing properties of concrete subjected to sulfuric acid attack. *Construction and Building Materials*, *115*, 486–495.

Yew, M.K., Mahmud, H. Ang, B.C and Yew .M.C (2014) Effects of heat treatment on oil palm shell coarse aggregates for high strength lightweight concrete. *Materials & Design*, 54, 702-707

Zamri, N,A. Properties of Oil Palm Shell Lightweight Aggregate Concfete Containing Palm Oil Fuel Ash. Master Thesis. Universiti Malaysia Pahang; 2015

Zeyad, A. M., Megat Johari, M. A., Tayeh, B. A., & Yusuf, M. O. (2016). Efficiency of treated and untreated palm oil fuel ash as a supplementary binder on engineering and fluid transport properties of high-strength concrete. *Construction and Building Materials*, *125*, 1066–1079.

Zeyad, A. M., Megat Johari, M. A., Tayeh, B. A., & Yusuf, M. O (2017)Pozzolanic reactivity of ultrafine palm oil fuel ash waste on strength and durability performances of high strength concrete, *Journal of Cleaner Production.* 144 511-522.

Zhai, W.J., Ding, J.Y., An, X.W. and Wang, Z.F. (2020) An optimization model of sand and gravel mining quantity considering healthy ecosystem in Yangtze River, China, *Journal of Cleaner Production*, 242, Article 118385

Zhang, B., & Poon, C. S. (2015). Use of furnace bottom ash for producing lightweight aggregate concrete with thermal insulation properties. Journal of Cleaner Production, 99, 94-100.

Zhong S. T., Hubadillah, S.K.,Mohd Hafiz DzarfanOthman Mohd Irfan Hatim Mohamed Dzahir Khong N.K., Nur Izzati Syaheerah Tendot Izadin Tendot, Ahmad Fauzi Ismail, Rahman M.A., Jaafar, J., Mohd Haiqal AbdAziz (2019) Influence of pre-treatment temperature of palm oil fuel ash on the properties and performance of green ceramic hollow fiber membranes towards oil/water separation application, *Separation and Purification Technology*, 222, 264-277 .

Zivica, V.and Bajza, A. (2001). Acidic attack of cement based materials — A review, Principle of acidic attack. Construction Building Material. 15: 331–340